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ORTHOPAEDIC SURGERY

Posttraumatic and postoperative osteomyelitis: surgical revision strategy with persisting fistula

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Abstract
Introduction Posttraumatic and postoperative osteomyelitis (PPO) with bacteria colonisation during trauma and associated surgery is an increasing clinical problem. This study investigated the treatment of PPO by surgical revision including irrigation, debridement, and temporary hardware maintenance. In addition, a drainage was inserted as persisting fistula to control osteomyelitis until fracture healing was achieved. Trauma- and osteomyelitis-related factors that influenced the study outcome were determined.
Patients and methods 67 consecutive patients with PPO were included. At onset of PPO, patients had incomplete fracture healing. Patients were subdivided by time of PPO occurrence (acute, subacute or chronic), initial soft tissue trauma, anatomical location, and initial fracture type (AO classification). The study outcome measures included radiographic and clinical follow-up.
Results 59 patients could be followed for an average of 23 months after revision surgery. A bone healing was achieved by 89 % of patients after 14.7 ± 13.4 weeks. Fractures of the lower extremity, open fractures and comminuted C-type fractures took significantly longer to achieve bone healing ($p < 0.05$ each). Time of PPO occurrence did not influence bone healing. After fracture consolidation, no re-infection was found.
Conclusions This study showed high rates of bone healing, indicating that this strategy with persisting fistula should be considered as alternative treatment option in patients with PPO.

Keywords Osteomyelitis · Hardware maintenance · Temporary drainage · Persisting fistula

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Introduction

Posttraumatic and postoperative osteomyelitis (PPO) is one subtype of osteomyelitis with increasing prevalence and extends to approximately 80 % of all cases [1]. Its pathophysiology of bacterial inoculation could be provoked by a direct contamination during trauma—particularly in open fractures [2], or during associated fracture fixation surgery [1]. The point of clinical onset of PPO symptoms is relevant, and their appearance can be divided into an acute PPO (within 2 weeks after trauma or surgery), a subacute

PPO (2–6 weeks), or with transition to a chronic PPO (>6 weeks) [1].

Many risk factors for the development of a PPO have been identified recently. One important pathophysiologic factor with increasing attention is the invincible bacterial biofilm attached to fixation implants [3]. Further risk factors for bacterial soft tissue, bone and implant-related infections include extrinsic factors such as fracture severity and soft tissue damage [4]. Accordingly, the rate of infection varies from 1 to 5 % for open reduction and internal fixation and is increased to much higher rates in open, comminuted fractures [5–11]. Intrinsic patient contributing factors include a high or very low age and relevant comorbidities such as liver or kidney insufficiency, or malignancies.

Currently, there is no evidence-based standard treatment for patients with PPO. Particularly in patients with PPO onset before fracture healing was completed, we reported great variability of strategies among the surgeons. The discussed conflict was whether to maintain or remove the internal fixation device. Most surgeons recommend a rather aggressive surgical strategy with radical debridement and removal of all internal implants [12]. Generally speaking, the maintenance of the biofilm-covered implants may contribute as additional risk factor for persisting or re-occurring chronic osteomyelitis [13]. Thus, internal implants are often removed and replaced by external fixators. However, treatments with external fixators require high patient compliance and are associated with considerable complication rates as well as prolonged duration of treatment [11].

On the other hand, a mechanical stability is also important for an adequate bone healing [14]. Therefore, only few authors consider at least temporary implant retention and suggest eradication of infection once bone healing is completed [15]. As one implant-retaining approach, the aim of the current study was to introduce a revision strategy including internal implant maintenance to guarantee mechanical stability, while local bone infection is controlled by a persisting fistula. We report on our experience in patients with insufficient fracture healing at onset of PPO and show results of our surgical revision strategy, including irrigation, debridement and implant retention with insertion of an implant drainage (persisting fistula) until fracture healing.

Patients and methods

Study population

This retrospective study obtained approval of the local ethical review committee [review number 837.117.12(8218)], and included 67 consecutive patients with PPO from 2008 to 2011 treated at our trauma centre. Mean patient age was 52 years (14–95) (Fig. 1). Relevant patient comorbidities

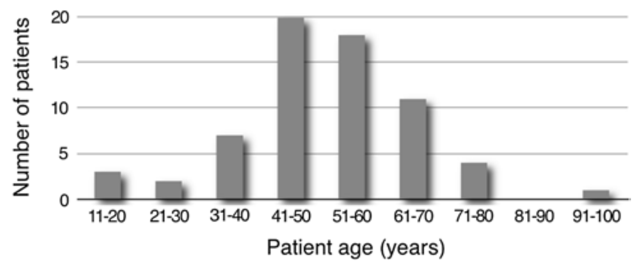

Fig. 1 Age distribution of study population

included diabetes, hypertension, obstructive lung disease, epilepsy, chronic liver and kidney diseases, nicotine abuse, or cancer. 79 % of all patients had at least one comorbidity, and 18 % had two or more comorbidities. Initial fractures were fixed by plates, screws or wires or external fixators; patients with intramedullary nails were not included, either due to fracture type and localisation, or to concomitantly soft tissue injury.

The total study population was subdivided by (a) anatomic location of the fracture/PPO: upper extremity ($n = 20$) or lower extremity ($n = 41$) and pelvic fractures ($n = 6$); (b) soft tissue conditions according to the classification of Gustilo and Anderson [6]: open ($n = 11$) or closed fractures ($n = 56$); (c) fracture severity according to the AO classification (Müller AO classification): A + B types ($n = 37$) vs. C types ($n = 30$); and (d) time of PPO occurrence after fracture: PPO <2 weeks after fracture stabilisation ($n = 28$), PPO 2–6 weeks after fracture stabilisation ($n = 28$), or PPO >6 weeks after fracture stabilisation ($n = 11$) [1].

Study inclusion and exclusion criteria

Each patient with PPO showed an incomplete fracture healing at onset of PPO. The decision for revision surgery was made by local signs of infection (pain, swelling, redness, wound secretion), and systemic signs of infection (triple C-reactive protein elevation, temperature >37.5 °C, and elevated leucocyte counts).

The study exclusion criteria were: (a) loss of fistula within 4 weeks postoperatively, (b) sepsis, (c) soft tissue damage with need of flap during PPO, (d) re-occurrence of chronic osteomyelitis >1 year after trauma, or (e) disagreement with informed consent. Patients with PPO and severe tissue defects (c) received a vacuum-assisted therapy to improve soft tissue conditions. Approximately 20 patients were excluded as they showed severe soft tissue damage (c).

Revision surgery concept

After wound opening, a sample from the infected bone was sent to microbiology. The diagnosis of PPO with local bone infection was verified by macroscopic findings of local bone infection with osteonecrosis, loosening of screws or purulent fluids within the bone. Then a local, but radical debridement of necrotic bone and soft tissue was done, particularly at the infected fracture site, followed by irrigation with pulsed lavage. All implants remained in place and were cleaned and brushed; occasionally loose screws were replaced by longer screws if possible. A drainage (size 14–16 Charriere) was inserted as persisting fistula with contact to the implant before wound closure. Postoperatively an antibiotic therapy was initiated with a cephalosporin, and adjusted according to the resistogram if necessary. Antibiotics were maintained for at least 4–8 weeks, depending on local wound conditions. Patients were mobilised and obtained physiotherapy with increasing weight bearing postoperatively. After patient dismissal, a general practitioner supervised the wound healing and drainage secretion. Most important issue was a sufficient vacuum within the drainage flask. The flask was renewed regularly (1–2*x*/week). The maintenance of the persisting fistula depended on fracture and wound consolidations. The drainage and hardware removal were intended to be done simultaneously approximately 6–8 weeks after revision.

Clinical and radiographic outcome parameters

The mean follow-up period was 23 months (6–54 months). Within the follow-up period, patients were monitored closely. Standardised questionnaires and patient interviews were done during treatment to determine clinical outcome and re-infection rates after bone consolidation. The questionnaires determined implant removal, return to work and daily (sports) activity, ability of weight bearing and re-occurrence of osteomyelitis with required additional surgery.

The detailed radiographic outcome was evaluated by a modified radiographic score adopted from Bahrs et al. [16]. The parameters included (a) secondary fracture dislocation, (b) radiographic signs of bone infection (sequestrae, osteolysis), (c) implant-related complications, (d) bone consolidation (evaluated by % of callus formation and visibility of fracture gab), and (e) surgeon's intraoperative evaluation of mechanical stability after implant removal. Each parameter was rated from 0 to 2, whereas lower numbers indicated a better outcome of the score. The result was very good (0–2 points), good (3–4), acceptable (5–6), or bad (>6). A re-occurrence of osteomyelitis or inadequate bone consolidation was both rated as treatment failure.

Statistics

Mean and standard deviation (SD) were calculated for continuous, mean and median for ordinal variables. Primary outcome parameter was bone consolidation. Association between bone consolidation and a variable was tested by Student's *t* test in case of two discipline groups, or in case of three discipline groups the outcome variables were tested in a one way analysis of variance for differences between the discipline groups.

Results

Study population and intraoperative findings

The average number of PPO-related revision surgeries before drainage implantation was 1.8 (1–7), though some patients had several previous revision surgeries (maximum 7). 55 % of patients underwent the current revision concept during first revision surgery after internal fracture fixation.

Microbiological results showed that 91 % of patients had positive intraoperative bacterial detection within the bone tissue, confirming the osteomyelitis. 28 % of the patients had a methicillin sensitive *Staphylococcus aureus*. The diversity of bacteria included 22 different species (Fig. 2). In seven patients (9 %) no bacteria growth could be detected within 14 culture days despite intraoperative clinical signs of PPO with bone infection.

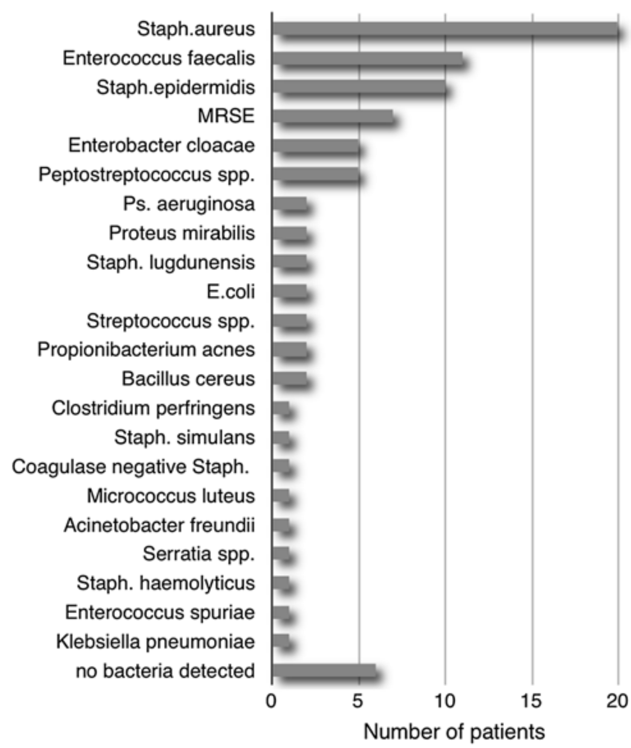

Fig. 2 Variety of detected microorganisms during revision surgery

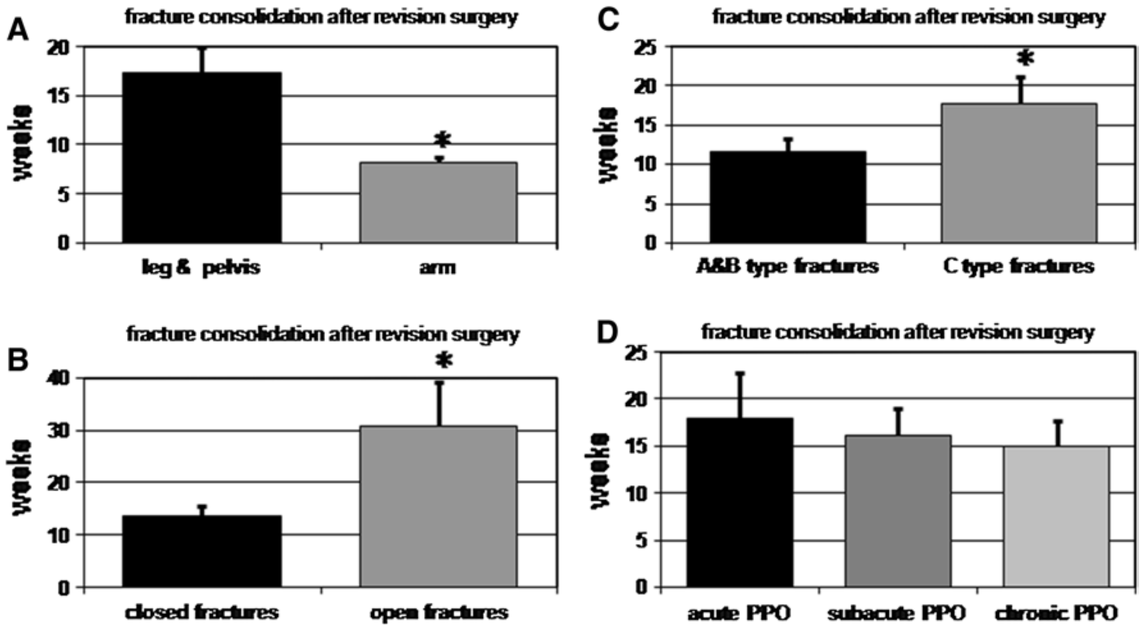

Fig. 3 Fracture consolidation rates with full weight bearing depending on: **a** anatomical localisation (upper and lower extremity); **b** open vs. closed fracture; **c** A&B type of fracture vs. C-type fracture; **d** clinical onset of PPO: acute, subacute and chronic. Statistically significant results were marked

Clinical and radiographic long-term results

From a total of 67 patients, 59 could be followed. 6 patients were lost to follow-up, and two patients died due to non-surgery related reasons ($n = 2$). Overall, a bone consolidation was achieved in 89 % of the patients ($n = 53$) after an average of 14.7 ± 13.4 months.

As part of the study, bone consolidation was analysed in relation to (a) anatomical location, (b) soft tissue damage, (c) fracture severity, and (d) time of PPO occurrence. The results showed that bone consolidation was achieved after (a) 17.4 ± 2.6 weeks (leg and pelvis), or 8.3 ± 0.5 weeks (arm) ($p = 0.008$); (b) after 30.9 ± 2.4 weeks in open fractures, 13.1 ± 0.3 weeks in closed fractures ($p = 0.001$); (c) 11.5 ± 1.8 weeks in A + B type, 17.7 ± 3.4 weeks in C-type fractures ($p = 0.04$); (d) 17.9 ± 4.9 weeks in acute PPO (<2 weeks after fracture stabilisation), 16.2 ± 2.9 weeks in subacute PPO (2–6 weeks after fracture stabilisation) and 15 ± 2.7 weeks in chronic PPO (>6 weeks after fracture stabilisation) (both $p > 0.05$ vs. acute PPO) (Fig. 3).

After clinical follow-up, all patients with bone consolidation returned to previous daily and sports activity and to professional life.

Implant removal

40 patients (68 %) underwent implant and fistula removal after fracture consolidation. During metal removal the bone structure around the fracture site did not show signs of osteomyelitis. 3 patients had limited weight bearing postoperatively due to incomplete mechanical stability; all others beared full weight. During follow-up no re-fracture or re-infection occurred, and clinical follow-ups remained unremarkable. Despite intended early metal removal after fracture consolidation, implants were maintained in 13 patients (22 %) as they remained completely asymptomatic after fistula removal. Within the follow-up period, no re-infection occurred despite hardware maintenance.

Radiographic score

The overall radiographic score at time of implant removal was 2.3 ± 2.08 ($n = 29$), demonstrating an overall good to very good result. Patients with fractures of the upper extremity were significantly better than those with fractures of the lower extremity and pelvis (1.8 ± 1.4 vs. 2.75 ± 2.6; $p < 0.05$). The radiographic score was not obtained in 24 patients, since either no metal had been removed ($n = 13$; no intraoperative stability testing), or the patients turned out asymptomatic ($n = 11$), or a combination of both. Patients with humeral head osteonecrosis obtained the maximal score of eight points.

Figure 4 illustrates each included patient schematically, Fig. 5 shows a complex tibial and fibula fracture with PPO after bone grafting, and Fig. 6 shows a clinical picture of drainage in place at the femur.

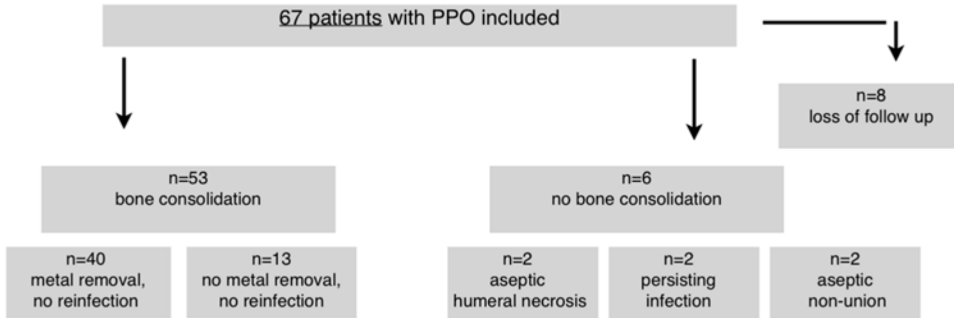

Fig. 4 Schematic study population outcome

Fig. 5 Clinical case of third degree open comminuted tibial and fibula fracture. Injury day (**a**) with external fixator and fibular wire osteosynthesis. Due to concomitant severe chest trauma and soft tissue injury, intramedullary nailing was not indicated. Osteosynthesis included a LC-plate with simultaneous free flap transplantation for soft tissue coverage (**b**). After transplantation of bone graft to the proximal tibial fracture PPO occurred with revision surgery with insertion of drainage (**c**) for 7 weeks. **d** the result 11 months postoperatively with tibial consolidation to be achieved. The implant was not removed simultaneously with the drainage in this case

Fig. 6 Clinical picture of a drainage kept after PPO after a 3° open femur fracture

Complications and failures of treatment

2 patients achieved no bone consolidation, but developed an aseptic non-union, requiring re-osteosynthesis with Ilizarov type fixator. 2 patients suffered of persisting osteomyelitis and developed septic non-union, which required a bone segment resection with external fixator, followed by bone distraction. Due to comminuted fractures of the proximal humerus, two patients developed aseptic head osteonecrosis and received arthroplasty. No other complications were observed during follow-up period. A risk factor analysis showed no association of complication with time of clinical onset of PPO or initial soft tissue damage. In fact, a clear association between non-union and severity of initial bone trauma was found: all revision surgeries due to treatment failure were owing to comminuted fractures.

Discussion

Here we investigated patients with posttraumatic and postoperative osteomyelitis (PPO) and the clinical outcome after surgical revision with debridement, irrigation and insertion of a persisting fistula. The fistula was inserted to control PPO until fracture consolidation was achieved, while fracture fixation implants remained in place. The study outcome showed an overall bone consolidation in 89 % of the patients with full weight bearing after 14 weeks. No re-infections occurred within the study follow-up period.

One important study aim was to identify trauma- and osteomyelitis-related parameters that could influence bone consolidation after this revision concept. Therefore, we investigated the influence of initial fracture severity according to the AO classification [17], the onset of PPO (acute, subacute or chronic PPO), the initial soft tissue condition (open or closed fracture) and the anatomic location (upper or lower extremity with pelvis). While onset of PPO did not affect bone consolidation, bone healing took longer in patients with open, comminuted C-type fractures and fractures of lower extremity, indicating that fracture severity and soft tissue damage may be a relevant trauma-associated parameter to predict the clinical outcome once PPO has occurred.

The fact that onset of PPO did not correlate with clinical outcome was surprising. A sub-classification by onset time of osteomyelitis has been suggested to become a predictive parameter [1], although an exclusive separation by time of onset might not be reliable, since the outcome in addition depends on many host variables, i.e. status of immune system and comorbidities. The detailed pathophysiologic route of bacterial inoculation remains unclear. Osteomyelitis could be initiated by bacterial inoculation during trauma (posttraumatic osteomyelitis), or during fracture fixation (postoperative osteomyelitis), respectively. Both routes may contribute to the bone infection, thus we here refer to “posttraumatic & postoperative osteomyelitis” (PPO), in agreement with others [1].

In the current study, we chose the controversial strategy of implant maintenance combined with a persisting fistula while treating patients with PPO. In current literature, there is only one report on a persisting fistula [18]. However, this study addressed patients with periprosthetic infection and high operative risk due to multiple comorbidities and high age. Thus, extensive revision surgery was impossible and the infection was meant to be controlled permanently by a persisting fistula as salvage pathway. In opposite to this strategy, we aimed to achieve fracture consolidation by early implant and fistula removal after bone healing.

Furthermore, not many data are available on implant maintenance in patients with PPO. Recently, Rightmire et al. reported a success rate of 68 % with considerable rates of non-unions. Consequently, maintaining the hardware in place in PPO is still considered as risk factor for re-occurrence of infection [13]. The high success rate of the current approach with a bone healing rate of 80 % might be attributed to the local infection control by the persisting fistula. This is the first study to report clinical results after the above-mentioned revision concept, although its first description was made by Willenegger et al. in 1969. Their rationale was that “the main effect of the drainage is the mechanical rinsing of detritus, wound fluid, blood and bacteria” [19]. In 1974, Klemm et al. [20] added: “If one is forced to maintain the implant because of insufficient bone consolidation, you should make allowance to the contradictoriness of implant maintenance and eradication of infection by persistent drainage and salvage”.

Patients with severe soft tissue defects during PPO were excluded. In agreement with the literature [21], it is our strategy to treat those patients by vacuum-assisted therapy to improve soft tissue conditions. However, bone healing may be unaffected by vacuum-assisted therapy. Therefore, therapy of osteomyelitis often turned out to be long and exhausting. In some reports, finally only 35 % of the initial implants were kept in place with up to six operations including vacuum-assisted therapy [22].

One major advantage of our surgical revision concept with persisting fistula is the less invasive procedure for the patient. More aggressive surgical strategies such as bone resection and distraction osteogenesis can be avoided at first, and only need to be addressed secondarily in very few cases ($n = 2$). On the other hand, handling of the drainage required patients' compliance, as the drainage needs to be mobilised daily to prevent clotting, while the drainage flask has to be renewed continuously.

This study has several noteworthy limitations. Due to the retrospective setup, no control group existed, neither did a non-surgical control group exist, as it is a general belief that an acute or subacute PPO cannot be treated without surgery. However, to verify the current knowledge in a prospective study, comparison with patients undergoing debridement and irrigation without persisting fistula might be useful, particularly to prove that the presented results are related to the drainage effect within the infected bone area. We lost eight patients during follow-up, therefore, the outcome of these patients is unclear. In chronic osteomyelitis, re-infection is possible even years after initial trauma. In contrast, our study patients showed rather early onset of symptoms. On the other hand, no such re-occurrence of osteomyelitis after our revision strategy was observed during follow-up period. We are aware that it is required to follow our patients further to exclude later re-occurrence of osteomyelitis.

In summary, the hereby described revision strategy in patients with PPO is easy and shows promising results. It thus may be considered as alternative treatment option, particularly in patients with non-comminuted fractures, before addressing more aggressive surgical strategies.

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Conflict of interest None.

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